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US 4005457 A

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UK CL (Edition Q) H1K KEAA KEAX KPADL KPX KPXB KRA
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ON LINE,W.P.I.

(54) Abstract Title
Light emitting diode

(57) A layer of opaque material 14 is interposed between the LED die 16 and the die-attach epoxy 20. The verall thermal resistance of the LED die is reduced by using a metal-filled epoxy 20 and by using a metal as the opaque layer. The overall light output of the LED lamp package may be further improved by selecting an paque metal layer to have a high reflectivity to the light that is emitted from the LED chip. Furthermore, an additional layer 10 may be interposed between the LED die 16 and the opaque material 14 to promote adhesion.

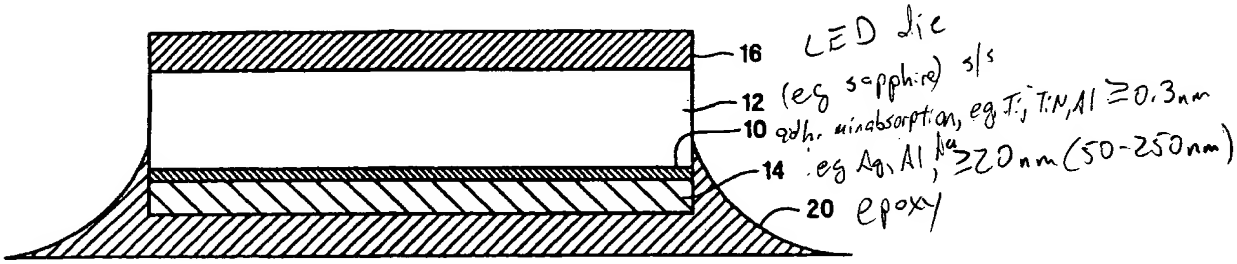

Figure 3

102: 1,4,6,14,26

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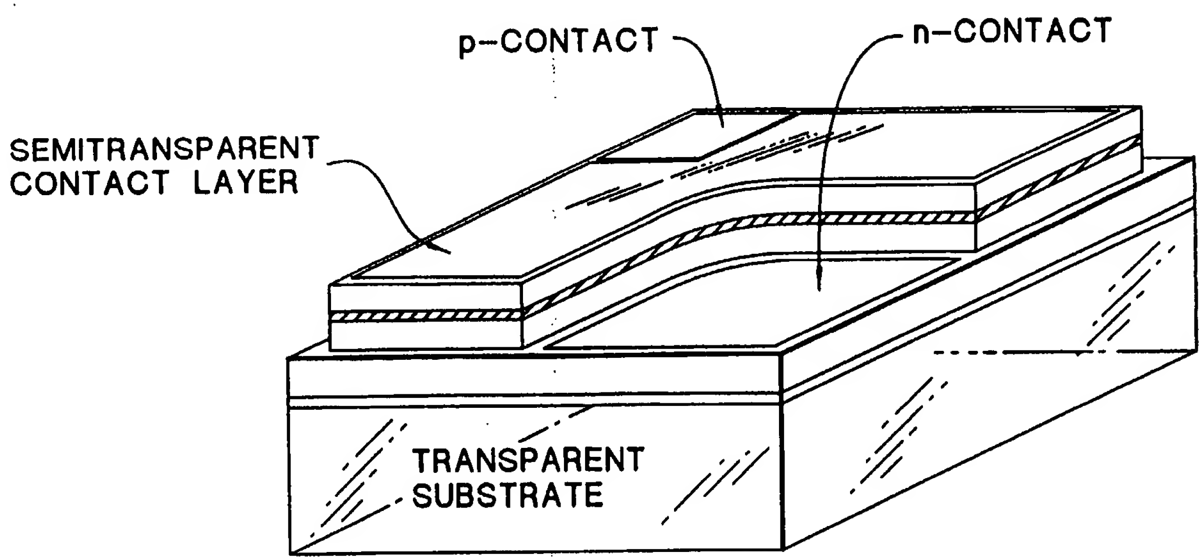

Figure 1 (PRIOR ART)

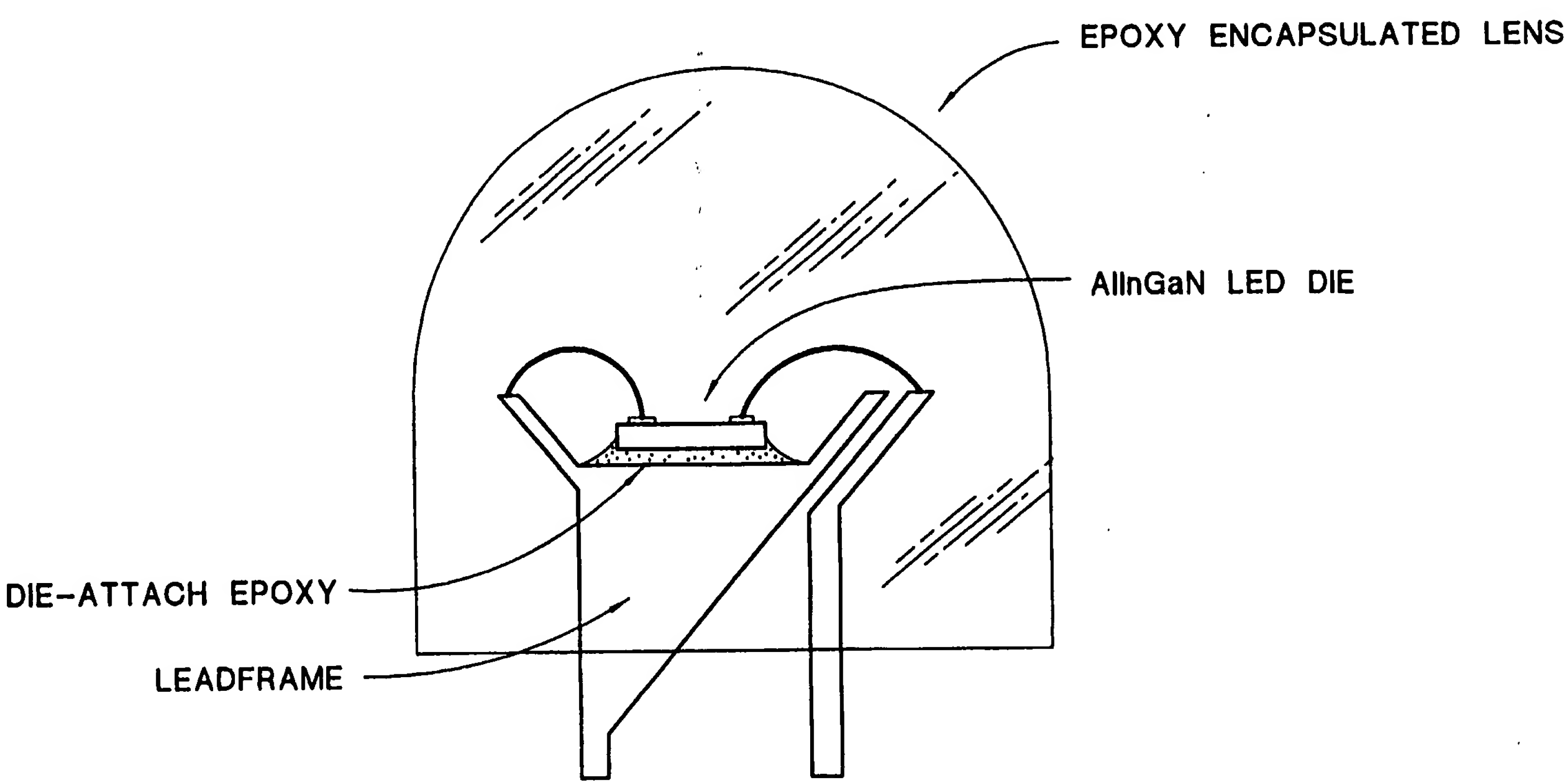

Figure 2 (PRIOR ART)

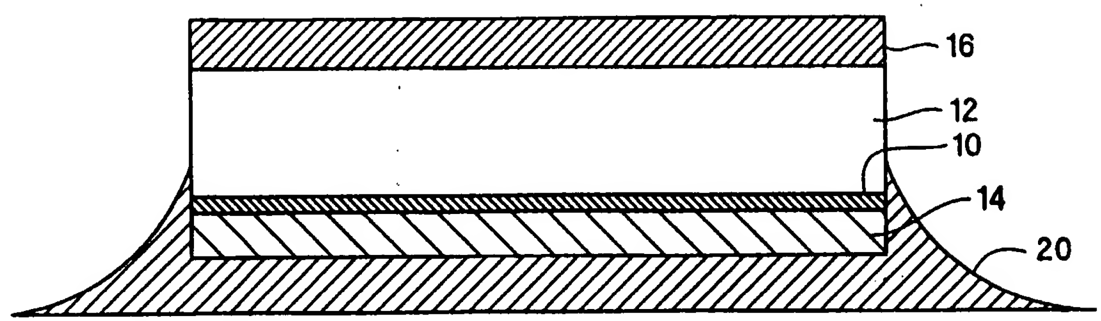

Figure 3

Back-Reflectance into Sapphire of 100-nm-thick Metal films deposited on Sapphire

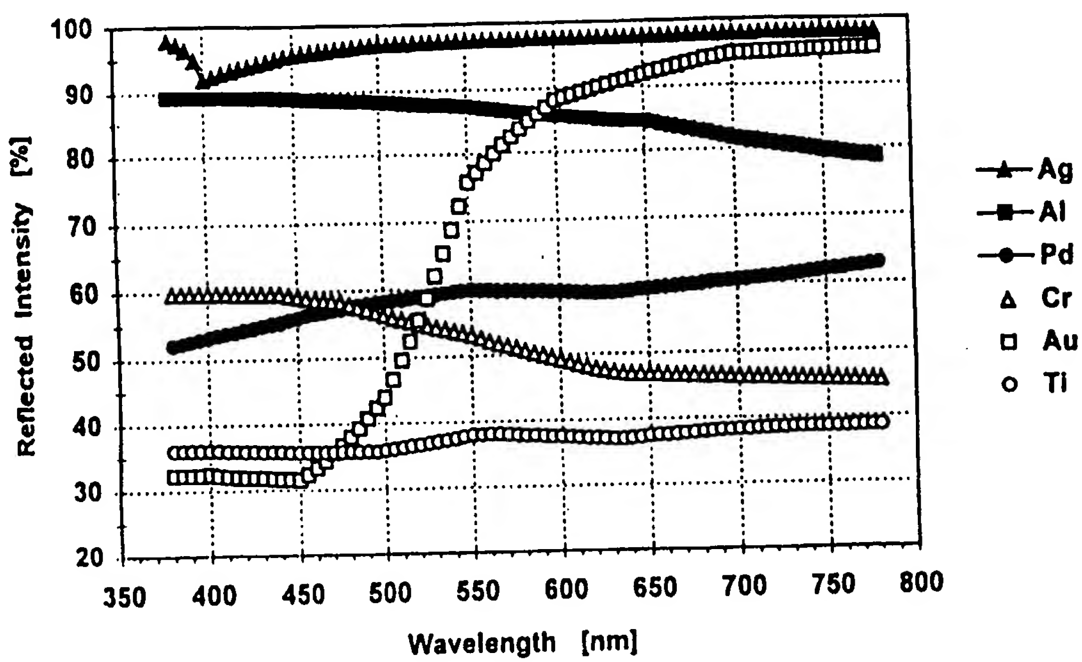

Figure 4

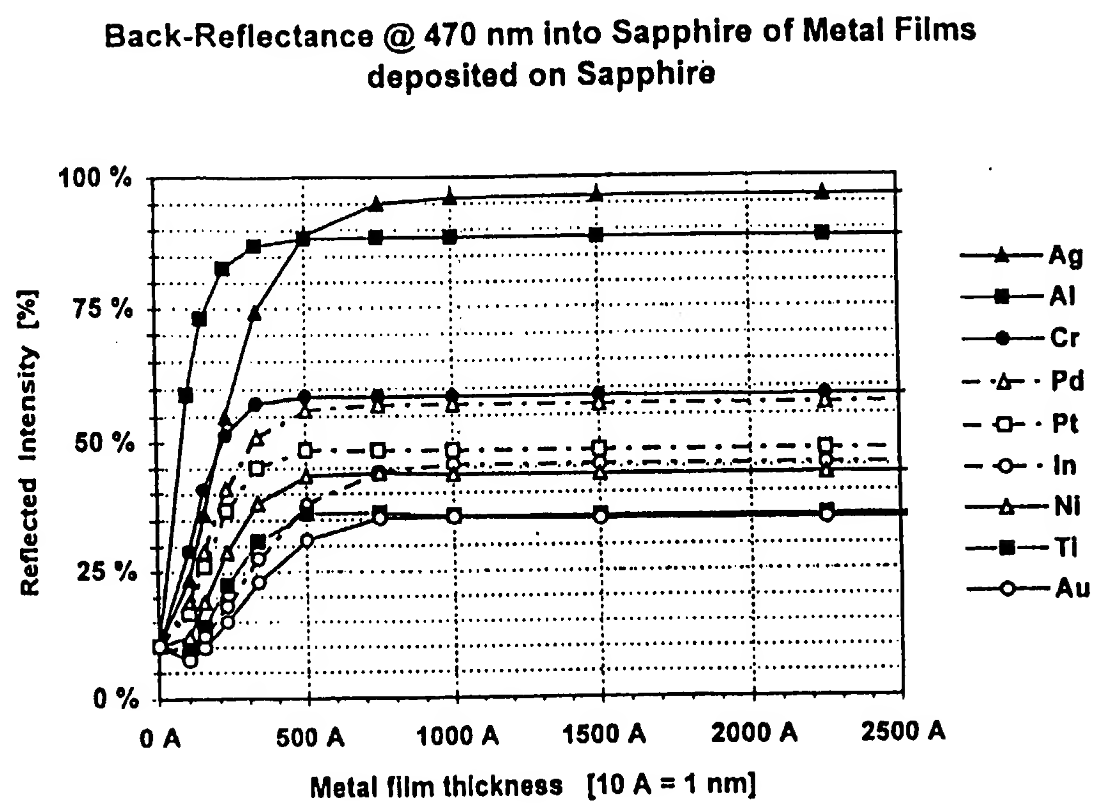
Back-Reflectance @ 470 nm into Sapphire of Metal Films
deposited on Sapphire
100 %
75 %
50 %
25 %
0 %
Reflected Intensity [%]
0 A
500 A
1000 A
1500 A
2000 A
2500 A
Metal film thickness [10 A = 1 nm]
Ag
Al
Cr
Pd
Pt
In
Ni
Tl
Au

Figure 5

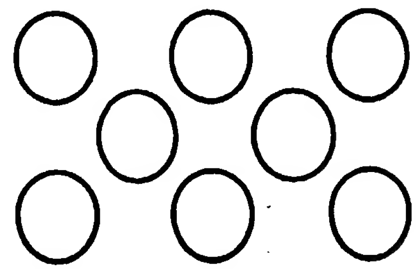

Figure 6A

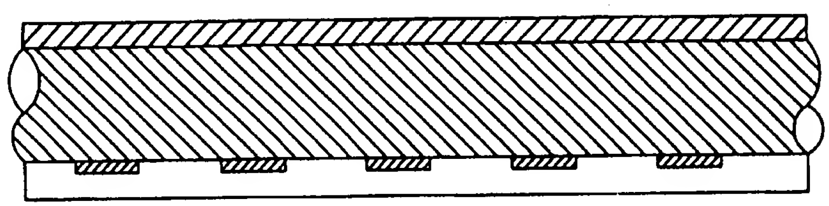

Figure 6B

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LIGHT EMITTING DIODE

The invention is directed towards the field of light emitting diodes, particularly towards the packaging of the die.

Current high-brightness light emitting diodes (LEDs) span the entire visible spectral range, with efficiencies comparable to or exceeding existing light sources. Due to the solid-state nature of these high-brightness LEDs, the reliability behavior is significantly improved over incandescent and fluorescent lighting technologies. There is an expectation that commercial LEDs will operate continuously in excess of 100,000 hours having a degradation of light output of less than 50% of the initial value. In addition, there is a greatly reduced incidence of catastrophic failure that allows users to implement preventive maintenance schedules to replace LEDs before failure.

High-brightness LEDs that emit light in the violet through green spectral regions have been developed using the AlInGaN materials system. The potential market applications for these emitters are quite sensitive to the degradation performance, hence the LED degradation is one of the critical parameters to consider for the success of this technology. Existing commercial AlInGaN LEDs have been shown to have excessive levels of degradation and useful device lifetimes of approximately 3500 hours for high-brightness blue LED packages. This poor reliability performance is due in part to degradation of the die-attach epoxy that reduces the light output of the LED through internal absorption of the emitted light.

All commercial high-brightness AlInGaN LEDs are currently produced using a transparent, electrically insulating sapphire substrate, as shown in Figure 1. The election of sapphire for the substrate for the epitaxial growth of the LED structure is selected for two main reasons. First, sapphire is extremely thermally and chemically robust, and is capable of withstanding the high temperatures encountered during epitaxial growth, along with the corrosive environment of ammonia gas that is used for the growth. Second,

sapphire is extremely transparent to the light in the violet through green spectral region which enables the growth of a transparent substrate LED, leading to the potential for high efficiency LED manufacture.

Figure 2 schematically illustrates how such an LED chip is mounted into a common LED lamp package. The AlInGaN LED die is physically connected to the metal leadframe with the use of a die-attach material. The die-attach material is commonly an epoxy resin, either clear or filled with a high density of metal flakes that allow it to conduct electricity and to have improved thermal conductivity. The LED die and leadframe are then encapsulated into a transparent, rigid material for structural integrity, for improved optical performance, and to seal the LED die from the ambient environment. In such a configuration with an AlInGaN LED die, a transparent die attach epoxy is commonly used to maximize the total light output of the LED lamp. There are many other package types which differ from that illustrated in Figure 2. These include, but are not limited to, LED die that are mounted onto a ceramic substrate, or directly onto a printed circuit board. Similar processes are used to attach the LED chip onto the leadframe or substrate.

The present invention improves the reliability of LED packages produced from the AlInGaN materials system by addressing the degradation of the epoxy systems that are used for attaching the LED semiconductor die to the metal leadframe, i.e. the die attach epoxy material.

An opaque material interposes the transparent substrate of the LED die and the die attach epoxy to eliminate the degradation associated with increasing absorption in the die attach material during operation. The use of an opaque layer allows the use of a metal-filled die attach material which has reduced thermal resistance, but higher optical absorption. The overall thermal resistance of the LED lamp can be reduced further through the use of a metal as the opaque layer that is inserted between the LED die and the die-attach epoxy. A higher thermal resistance leads to a higher operating temperature for the LED package. The light output of an LED is decreased and the degradation rate is increased as the operating temperature of the LED is increased. The overall light output of the LED lamp package can be improved if the opaque metal layer is chosen so as to have a high reflectivity to the light that is emitted from the LED chip. An optional thin barrier layer may be inserted between the transparent substrate and the opaque layer to promote adhesion.

Figure 1 illustrates a light-emitting diode.

Figure 2 illustrates a light-emitting diode mounted in a package of the prior art.

Figure 3 illustrates a light-emitting diode of an embodiment of the present invention.

Figure 4 illustrates results of calculations for reflectivity of various metals into sapphire as a function of the wavelength of the light.

Figure 5 illustrates results of calculations for reflectivity of various metals into sapphire as a function of the thickness of the metal deposition.

Figures 6A-B illustrate means of optimizing reflectivity of opaque layers while maintaining adequate adhesion.

As shown in the present invention, the reliability performance of LED packages produced from the AlInGaN materials system can be improved by addressing the degradation of the epoxy systems that are used for attaching the LED semiconductor die to the metal leadframe, i.e. the die attach epoxy material. A preferred embodiment of the present invention is shown in Figure 3. An optional barrier layer 10 is deposited directly onto the backside of the substrate 12, e.g. sapphire, followed by the deposition of the thick opaque layer 14. An LED die 16 is attached to a metal leadframe 18 with a die attach epoxy 20.

The layers of opaque materials 10, 14 interpose the backside of the LED die 16 and the die-attach epoxy 18. The layers of opaque material 10, 14 acts as a barrier to minimize the degradation associated with increasing light absorption in the die attach material during operation.

The overall thermal resistance of the LED die and package may be reduced by using a metal-filled epoxy 20 and by using a metal as the opaque layer 14. The overall light output of the LED lamp package may be further improved by selecting an opaque metal layer 14 to have a high reflectivity to the light that is emitted from the LED chip. Figure 4 illustrates results of calculations of reflectivity versus wavelength (color) for a variety of metals. A number of metals have high reflectivity, but the preferred embodiment employs a silver or aluminum layer, which have the highest reflectivity to light in the violet through green spectral region. The lower limit on the thickness of the opaque metal layer is determined by the fraction of light that is transmitted into the die-attach material. The fraction of reflected light is determined by subtracting from unity the fractions of absorbed and transmitted light. Figure 5 illustrates results of calculations of the reflectivity for various metals when they are deposited onto a sapphire substrate, versus the thickness of the metal layer. For the two metals with the highest reflectivity, i.e. silver and aluminum, the lower limit on the thickness is approximately 20nm, the thickness at which half of the light is attenuated.

There are often adhesion problems encountered with the use of a metal directly deposited onto the surface of a ceramic material such as sapphire. Adhesion of the

opaque layers to the transparent substrate becomes an issue at several of the manufacturing steps, such as die-attach and wire bonding. At the die-attach step, the LED chip is removed from an adhesive tape, and mounted onto the leadframe with die-attach epoxy. Electrical connections are made to the LED chip during the wire bonding step. The material must have adhesive properties that allow it to remain with the transparent substrate during the die-attach and wire bonding steps. In addition, adhesion of the opaque layers to the transparent substrate is important for LED reliability because differences in thermal expansion coefficients between the LED die and the package can cause stress that leads to failure.

One solution to this problem is to insert an optional barrier layer, a thin layer of a second material between the transparent substrate and the opaque metal layer to promote adhesion. The material is chosen so as to have a minimum absorption of the emitted light. Optimal candidates include titanium or titanium nitride, and aluminum. The thickness of the barrier layer is chosen to optimize adhesion while not reducing the overall reflectivity of the opaque layers. The lower limit on the thickness is determined by adhesion properties, and may be as thin as one atomic layer, or approximately 0.3nm in thickness.

Figures 6A-B illustrate additional means for optimizing reflectivity of the opaque layers while maintaining adequate adhesion. Figure 6A describes one possible pattern for partial coverage of the adhesion layer. Figure 6B schematically illustrates a cross-sectional view incorporating the concept described in Figure 6A. The layer that is optimized for adhesion is patterned in a manner which results in partial coverage of the material with lower reflectivity, and partial coverage of the material with highest reflectivity. Such a process can be developed to provide the maximum reflectivity with adequate adhesion.

The present invention, although described with respect to leadframes, is extendible to other packaging technologies, e.g. ceramic substrates or printed circuit boards. Those with ordinary skill in the art will fabricate the LED to reduce its contribution to package degradation prior to finished assembly.

CLAIMS

1. An LED assembly comprising:

a light-emitting diode, having a transparent substrate;

an opaque layer on the transparent substrate;

a layer of die-attach epoxy on the opaque layer; and

a leadframe, attached to the layer of die-attach epoxy;

wherein the opaque layer is operative to reduce the degradation of the die attach epoxy.

2. An LED assembly, as defined in claim 1, wherein the die-attach epoxy is a metal-filled epoxy operative to reduce the thermal resistance of the LED assembly.

3. An LED assembly, as defined in claim 1 or 2, wherein the opaque layer is a metal.

4. An LED assembly, as defined in claim 3, wherein the metal is chosen to have a maximum reflectivity to the wavelength of light that is emitted from the LED die.

5. An LED assembly, as defined in claim 3 or 4, wherein the metal is selected from a group that includes silver, silver alloy, aluminium and aluminium alloy.

6. An LED assembly, as defined in any of claims 3 to 5, further comprising a barrier layer interposing the transparent substrate and the metal layer, covers a fraction of the transparent substrate, to improve the adhesion of the metal to the transparent substrate.

7. An LED assembly, as defined in claim 6, wherein the barrier layer is chosen to optimize adhesion.

8. An LED assembly, as defined in claim 6 or 7, wherein the barrier layer is a metal.

9. An LED assembly, as defined in claim 6 or 8, wherein the barrier layer is chosen to optimize reflectivity.

10. An LED assembly, as defined in claim 6 or 7, wherein the barrier layer is selected from a group that includes titanium, titanium nitride and aluminium.

11. An LED assembly substantially as herein described with reference to Figs. 3 to 6 of the accompanying drawings.

Application No: GB 9901716.2
Claims searched: All

Examiner: C.D.Stone
Date f search: 13 April 1999

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.Q): H1K(KEAA,KEAX,KPX,KPXB,KRA,KPADL)

Int Cl (Ed.6): H01L

Other: ON LINE,W.P.I.

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	US 4005457 SEMIMETALS	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.